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PROJECT THEMIS

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PROJECT MANAGEMENT USING GPSS/360

Technical Report No. 19

By

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May 1969

This research was performed under ARO-D Contract No. DAH CO4 68C 0002.

ABSTRACT

A number of examples of complex precedence relationships in project management networking are considered employing the GPSS/360 program. The examples illustrate that GPSS/360 can be employed to develop project management information not readily attainable employing standard project management programs.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

The purpose in undertaking this research was to determine if GPSS/360 could be used for network project management and to determine if it possessed unique capability not presently available in most standard project management programs. Typical shortcomings of existing programs to be considered in employing GPSS/360 were:

1. A limitation to either a constant in CPM or a beta distribution description in PERT for activity times.
2. An assumed deterministic path through a network based on the path with the largest sum of means of sequential activity times.
3. An inability to predefine certain specific precedence relationships in a probabilistic fashion.
4. Pre-defined precedence relationship independent of the dynamic state of the system.

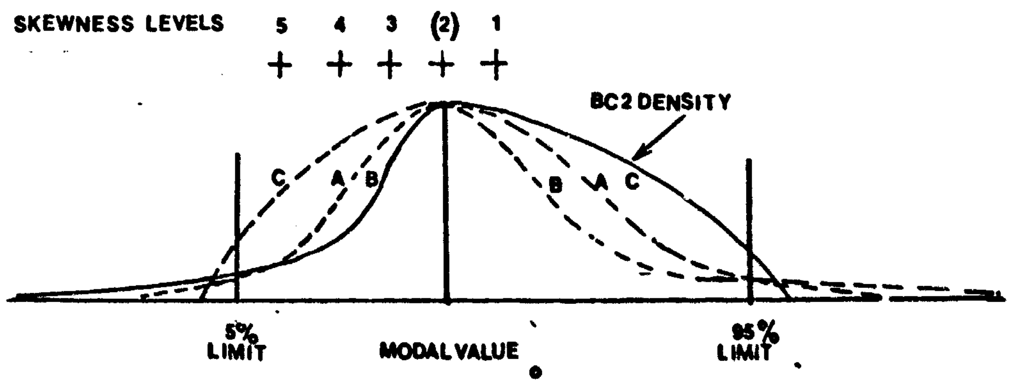
This paper contains examples developed to show how the above limitations can be overcome by employing GPSS/360 simulation. It is not proposed that project management programs be replaced by GPSS/360 programs, but rather that GPSS/360 models be employed to develop project management information not presently attainable employing standard network programs.

EXAMPLES OF GPSS/360 PROJECT MANAGEMENT CAPABILITY

Inputting Subjective Density Functions

A prior paper by the author [1] describes a method that was developed for inputting a density which fits a subjective description of the underlying density function for an activity time. The method involves selecting one curve from a family of 81 density functions by a process of elimination.

The family of 81 density functions is a consistent set of smooth unimodal density functions. The family has four levels of left and right skewness and one symmetrical set. Three levels of kurtosis for left and right segments of the distribution are provided. Figure 1 is one of the 81 curves skewed to the left at a level of 2 with a first level (i.e., B level) peakedness on the right segment and third level peakedness (i.e., C level) on the right side.



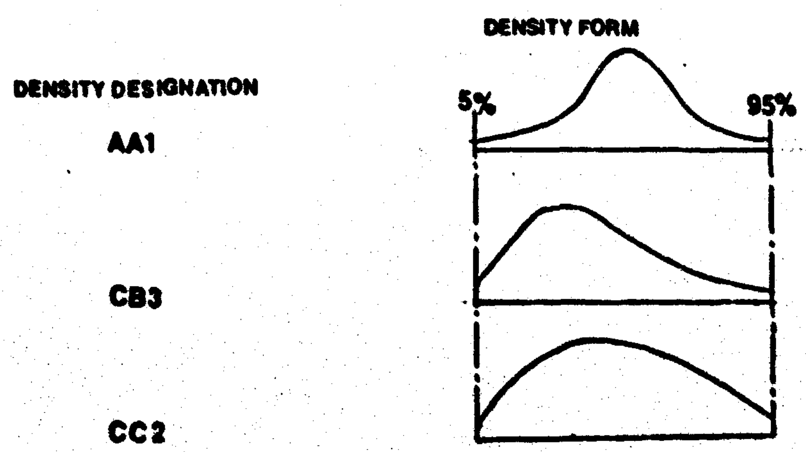
A SAMPLE SUBJECTIVE DENSITY FUNCTION

FIG 1

The BC2 curve shown in Figure 1 would have been selected by asking five questions concerning time for a specific activity. Answers to the five questions represent subjective estimates as to the modal lower 5% limit, upper 95% limit, and dispersion of the extreme values at both ends of the distribution as a clue to appropriate skewness level. Specific estimates for the five questions result in selection of one of the 81 curves as a closest approximation.

Although only one of the 81 curves is a mathematically expressable function (i.e., AA1 is normal between the 5% and 95% limits), the curves were drawn as a consistent set of density functions possessing smooth unimodal, variable skewness and variable kurtosis shapes.

When subjective estimates are the basis for the specification of an activity time density function, the above method is believed to permit more accurate specifications of the underlying density function. The methodology above also provides data cards for the density functions selected which meet the format requirements for inputting density functions into GPSS/360. Figure 2 illustrates three of the 81 density functions as example activity time distributions.



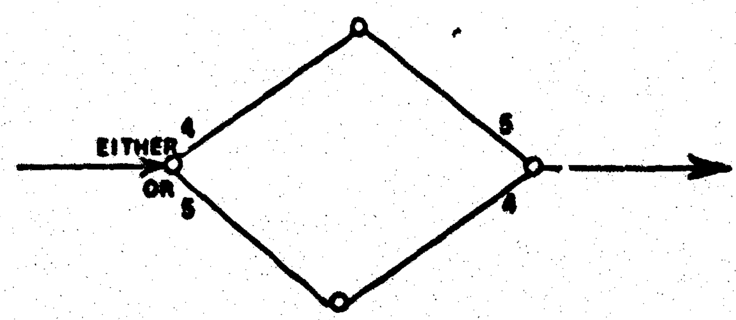
Example Activity Distributions

FIG 2

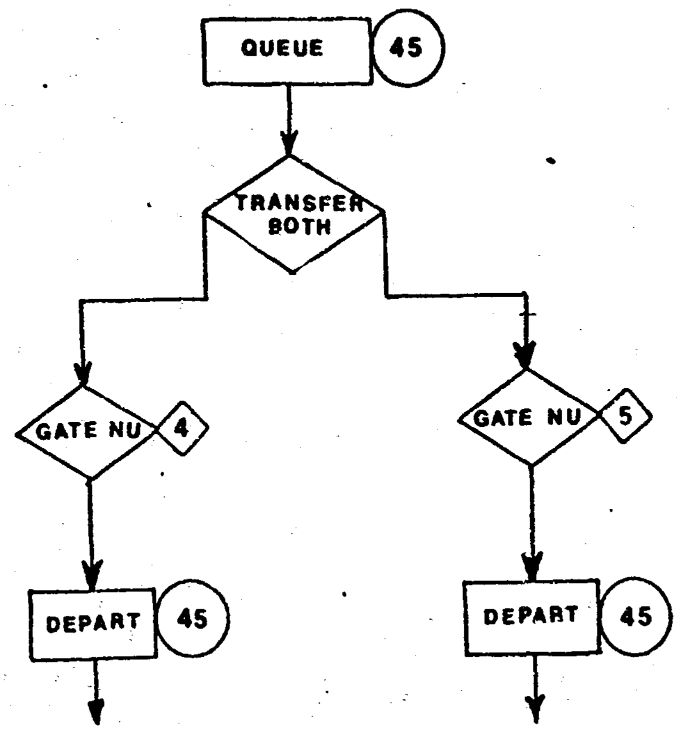
The function cards shown at the beginning of the program in Figure 4 are cards produced by a FORTRAN program employing the methodology mentioned above.

Either-Or Precedence Relationship

In CPM or PERT the order in which activities are to be performed is fixed in drafting the network. However, in many practical situations, the specific order in which two or more activities are to be sequentially performed may be relatively unimportant. Any fixed precedence relationship as would be required in CPM or PERT would be unnecessarily restrictive. A less restrictive precedence relationship is shown in Figure 3. The segment of a flow chart shown in Figure 4 would permit testing whether activity 4 or 5 can be entered. If one of the activities is blocked (e.g., a prior unit may be performing activity 4) then the other activity can be entered to hopefully shorten the time of completion for activities 4 and 5.



EITHER OR PRECEDENCE NETWORK
FIG 3

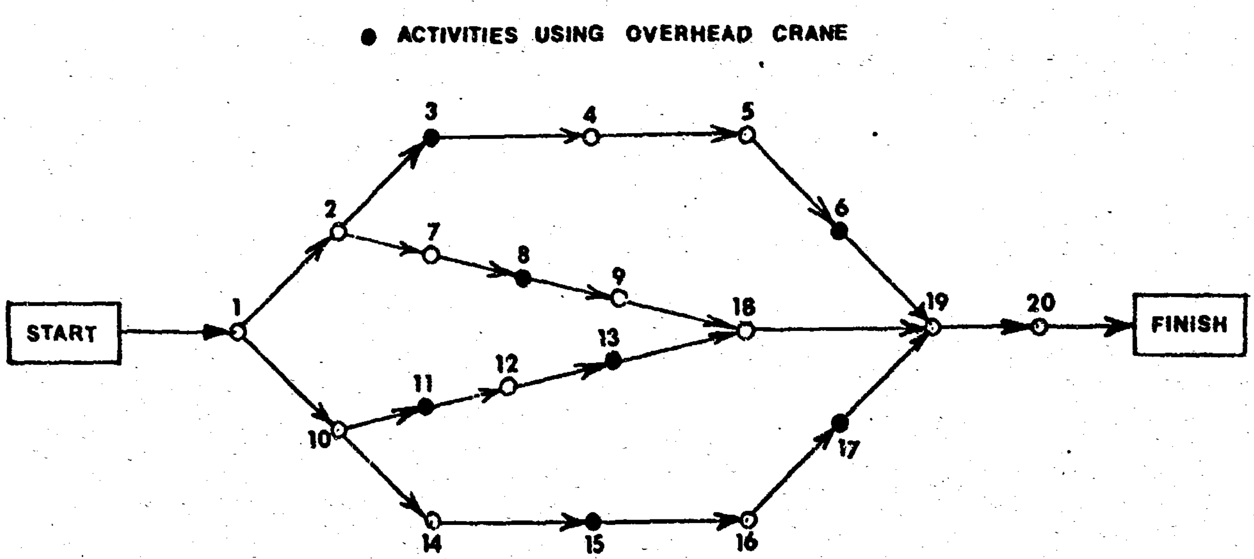


GPSS MODEL FOR EITHER-OR PRECEDENCE RELATIONSHIP
FIG 4

Probabilistic Critical Path

In CPM or PERT a unique path is designated as the critical path in a deterministic sense. In some networks, due to nearly equal sums of mean activity times, the probability of a unique path being critical is considerably less than one. In such a network, the probability of an activity being on the critical path is of considerable interest in valuing resource acquisitions in an effort to reduce the total project time. In Figure 5, any of the four paths in the network could conceivably be critical if each path has a near equal sum of mean times, and activity times for a single item

passing through the network are determined by sampling from the respective distributions for the activity times in a Monte Carlo fashion. For distributions specified by the method discussed in the previous section, the mean time for an activity may not even be known. Appendix A is a GPSS program for Figure 5 which permits specification of subjective density functions for activity times and also provides for Monte Carlo simulation of the network to determine the probability that an activity is on the critical path. For example, the probability that activity 5



PRODUCT ASSEMBLY NETWORK

FIG 5

is on the critical path can be readily determined by observing the percentage of non-zero time assignments to the parameters associated with activity 5. If in 100 starts there are 95 non-zero assignments to the activity 5 parameter, it is estimated that activity 5 has a 95% probability of being on the critical path. The program in Appendix A goes beyond estimating the probability of an activity being on the critical path as will be indicated in the next example.

Limited Resource Allocation

Assume that Figure 5 is a network for fabricating a product consisting of four assemblies. Assume also that operations 3, 6, 8, 11, 13, 15, and 17 represent handling operations employing an overhead crane. Appendix A is a GPSS/360 program developed to determine the effect on the distribution of the project completion times for the following three cases:

1. Each activity is assumed to have its own crane.
2. A common pool of cranes is assumed, with the size of the pool variable.
3. Assume there are two common pools, with the size of each pool variable.

In case 1, every activity has its own equipment and it is evident that the completion time for the project will be a minimum in this case. This is due to the fact that the waiting time, and hence the process completion time, which is the sum of all the processing times and waiting times for activities on the critical path, will be minimum.

Once again, the critical path was not fixed due to variable processing times and almost equal mean completion times for the 4 different

assembly routes. By running the simulation until a steady state was reached it was possible to find the probability that a certain path was critical. It was found that path A had the greatest chance of being critical, and hence the common equipment was allocated first to an activity on this path, so that the overall completion time would be minimized. As shown in Table I, the minimum completion time for the project was approximately 186 days. This is the case when each activity has its own independent crane.

In Case 2, the minimum number of common pool equipment desired was limited by the number of activities competing for the equipment. Therefore, the simulation was initially run with 7 cranes on hand. The number of cranes was gradually reduced to two. Table I shows the shift in the completion times as the number of cranes is decreased.

At no time were more than 5 cranes required simultaneously. The mean project completion time was not appreciably affected by decreasing the number of cranes to three, and the utilization of the cranes improved. As the number of cranes were decreased from three to two, however, we find that the mean project time increases considerably, indicating that three may be the desirable number of cranes to provide. This is further illustrated in Figure 6 which shows the distribution of completion times for a varying number of cranes. The distribution gradually shifts to the right, but for two cranes it suddenly shifts out of range (i.e., 125 to 270).

In case 3, it was assumed that activities 6, 13, and 17 were provided with a pool of equipment of its own. Thus, two groups of equipment were made as shown in Table I. In this case, it was found that a minimum of 4 cranes distributed as 2:2 between the two groups appeared to provide the most desirable results.

TABLE I

Crane Problem Output

No. of Cranes in Group 1	No. of Cranes in Group 2	Max Project Completion Time for 100 Trials	Mean Time	Utilization Group 1	Utilization Group 2	Std. Dev. About Mean	Max No. of Cranes Required Group 1	Max No. of Cranes Required Group 2
7	-	240	185.75	0.390	-	17.62	5	-
6	-	245	186.85	0.457	-	17.62	5	-
5	-	240	185.75	0.549	-	17.62	5	-
4	-	225	184.94	0.686	-	16.56	4	-
3	-	225	188.80	0.915	-	17.25	3	-
2	-	2790	2190.51	0.979	-	1146.0	2	-
4	3	235	190.18	0.289	0.382	17.62	3	3
4	2	240	195.08	0.292	0.583	16.43	3	2
3	3	250	197.09	0.392	0.386	19.25	3	3
3	2	250	198.38	0.385	0.576	22.12	3	2
2	2	250	197.45	0.578	0.574	19.37	2	2
2	1	923	888.33	0.487	0.971	406.00	2	1

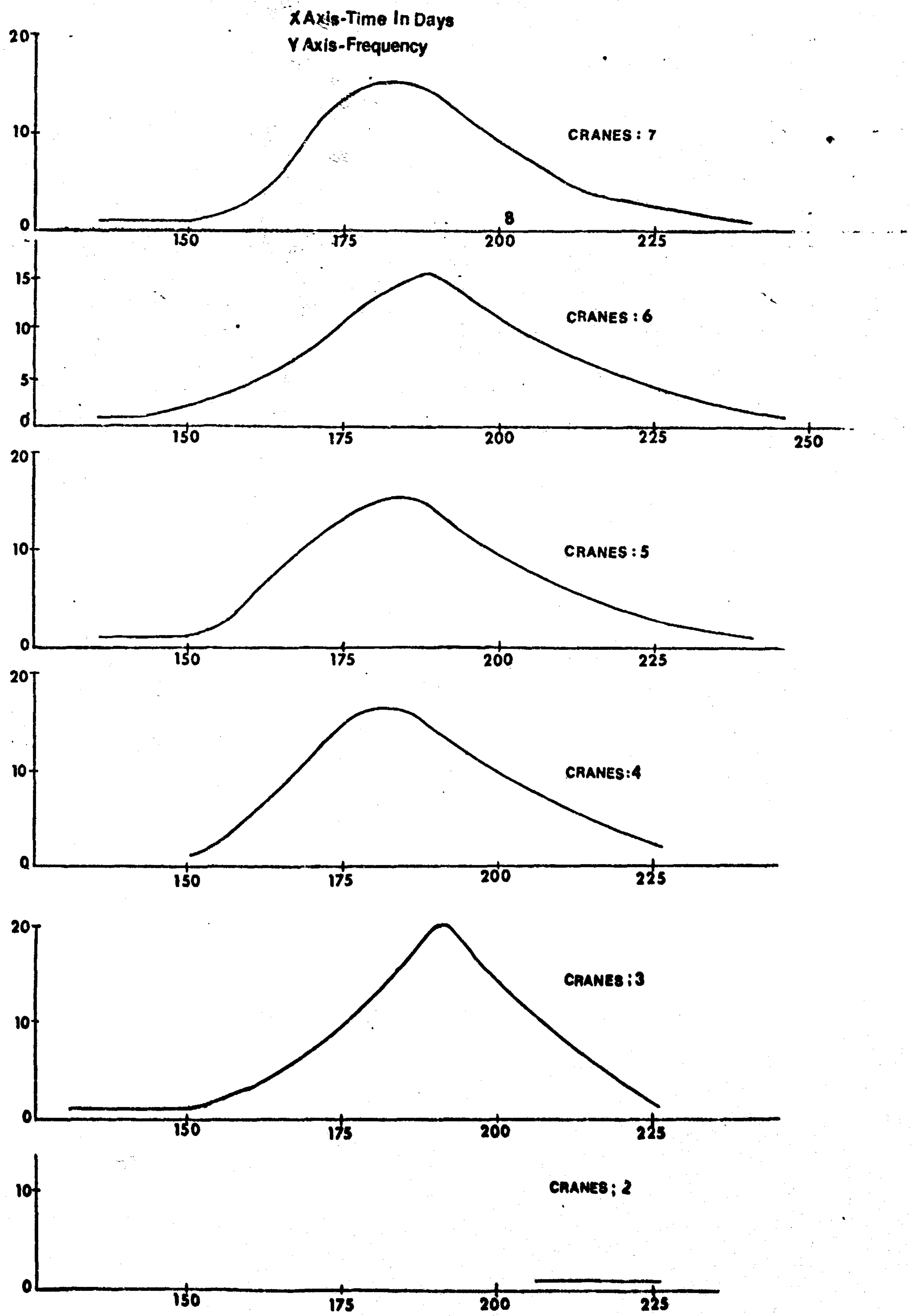

X Axis-Time In Days
Y Axis-Frequency
CRANES : 7
CRANES : 6
CRANES : 5
CRANES:4
CRANES ; 3
CRANES ; 2
150
175
200
225
250

FIG 6

Two groups of common equipment for this example proved to be preferable to one group. This would be true particularly where the distances between the various activity locations are large. However, a greater number of total equipment was required and the overall project completion time was increased by 5 to 7%. The time required to move the equipment from one location to another would also make the single pool less desirable.

CONCLUSIONS

The preceding examples serve to illustrate that considerable flexibility exists in utilizing the GPSS/360 program capability to derive project management information not readily attainable from standard project management programs.

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2. Moder, Joseph and Phillips, C., Project Management with CPM and PERT, Reinhold Publishing Corporation, New York 1964.

3. General Purpose Simulation System/360 User's Manual, Application Program H 20-0326, IBM Corporation, White Plains, New York, 1968.

APPENDIX A

GPSS/360 Network Model

```
* [illegible] ANALYSIS PROBLEM (JAI, SURESH KUMAR)
        SIMULATE
*FUNCTION DEFINITION CARDS
 1      FUNCTION    RN1,C17
[illegible] .00254-37.5 .[illegible]739-25.0 .01787-12.5 .05120  0.0 .11080 12.5
[illegible] 25.0 .33326 37.5 .49541 50.0 .65308 62.5 .78603 75.0 .88359 87.5
[illegible] .97639112.5 .99357125.0 .99770137.5 .99999150.0
 2      FUNCTION    RN2,C17
[illegible] .00202-25.0 .00003-12.5 .04775  0.0 .15401 12.5
[illegible] 25.0 .43501 37.5 .57954 50.0 .71001 62.5 .81535 75.0 .89488 87.5
[illegible] .97629 112.5 .99169125.0 .99861137.5 .99959150.0
 3      FUNCTION    RN3,C17
[illegible] .00202-25.0 .00204-12.5 .04836  0.0 .13715 12.5
[illegible] 25.0 .37177 37.5 .50043 50.0 .62963 62.5 .75281 75.0 .86406 87.5
[illegible] .99735112.5 .99597125.0 .99598137.5 .99559150.0
 4      FUNCTION    RN4,C17
[illegible] .00221-37.5 .00773-25.0 .02017-12.5 .04641  0.0 .10856 12.5
[illegible] 25.0 .42155 37.5 .58561 50.0 .71712 62.5 .82044 75.0 .89916 87.5
[illegible] .98144112.5 .99419125.0 .99916137.5 .99959150.0
 5      FUNCTION    RN5,C17
[illegible] .00002-25.0 .00842-12.5 .04860  0.0 .14497 12.5
[illegible] 25.0 .46656 37.5 .61319 50.0 .73739 62.5 .83351 75.0 .90388 87.5
[illegible] .97715112.5 .99133125.0 .99789137.5 .99959150.0
 6      FUNCTION    RN6,C17
[illegible] .00002-25.0 .00003-12.5 .04721  0.0 .19207 12.5
[illegible] 25.0 .50600 37.5 .63938 50.0 .75287 62.5 .83881 75.0 .90206 87.5
[illegible] .37[illegible]112.5 .99132125.0 .99846137.5 .99959150.0
        GENERATE    150,,,100,,40
        MARK        26
        ASSIGN      1,V1
        QUEUE       1
        SEIZE       1
        DEPART      1
        ASSIGN      21,GT1
        ADVANCE     V21
        RELEASE     1
        SPLIT       1,PATH6
        ASSIGN      2,V2
        QUEUE       2
        SEIZE       2
        DEPART      2
        ASSIGN      22,GT2
        ADVANCE     V22
        RELEASE     2
        SPLIT       1,PATH2
        ASSIGN      35,V51
        ASSIGN      3,V3
        JOIN        1
        ASSIGN      37,V23
        TRANSFER    ,CHAN
PATH2   ASSIGN      7,V7
        QUEUE       7
        SEIZE       7
        DEPART      7
        ASSIGN      27,GT7
        ADVANCE     V27
        RELEASE     7
        ASSIGN      8,V8
        ASSIGN      35,V52
        JOIN        2
        ASSIGN      37,V28
```

```
         TRANSFER  ,CHAN
PAIRS    ASSIGN    10,V13
         QUEUE     15
         SEIZE     10
         DEPART    1?
         ASSIGN    3?,CT10
         ADVANCE   V?C
         RELEASE   1?
         SPLIT     1,PAIR4
         ASSIGN    15,V34
         ASSIGN    11,V11
         JOIN      3
         ASSIGN    17,V31
         TRANSFER  ,CHAN
PAIR4    ASSIGN    14,V14
         QUEUE     14
         SEIZE     14
         DEPART    14
         ASSIGN    14,CT14
         ADVANCE   V24
         RELEASE   14
         ASSIGN    13,V13
         ASSIGN    1?,V??
         ASSIGN    37,V15
         JOIN      4
         TRANSFER  ,CHAN
CHAP     QUEUE     1?
         LINK      1,P32,JCE
JCE      ENTER     1C?
         DEPART    1CC
         EXAMINE   5,,PAL
         TRANSFER  ,CUP
PAL      EXAMINE   6,,TUP
         TRANSFER  ,C? P
TCP      EXAMINE   7,,P?P
         TRANSFER  ,CCP
PCP      ADVANCE   V14
         TRANSFER  ,CAL
CCP      ADVANCE   P31
         TRANSFER  ,CAL
CAL      LEAVE     1CC
         UNLINK    1,JCE,?10C
         EXAMINE   5,,SAV
         TRANSFER  ,RCG
SA?      EXAMINE   6,,SAV
         TRANSFER  ,RCG
RAV      EXAMINE   7,,TAV
         TRANSFER  ,RCG
TAV      ASSIGN    23,CT1CO
         EXAMINE   1,,GAT
         ASSIGN    4,V4
         QUEUE     4
         SEIZE     4
         DEPART    4
         ASSIGN    24,CT4
         ADVANCE   V24
         RELEASE   4
         ASSIGN    5,V5
         QUEUE     5
         SEIZE     5
         DEPART    5
         ASSIGN    25,C15
```

```
         ADVANCE     V25
         RELEASE     5
         TRANSFER    ,C[illegible]
  [illegible] ASSIGN  6,V6
         JOIN        2
         ASSIGN      31,V24
         TRANSFER    ,C[illegible]
  [illegible] EXAMINE 2,,[illegible]
         ASSIGN      9,V[illegible]
         QUEUE       4
         SEIZE       4
         DEPART      4
         ASSIGN      2,,[illegible]
         ADVANCE     [illegible]
         RELEASE     4
         TRANSFER    ,[illegible]
  [illegible] EXAMINE 3,,[illegible]
         ASSIGN      12,V12
         QUEUE       12
         SEIZE       12
         DEPART      12
         ASSIGN      [illegible],[illegible]12
         ADVANCE     V12
         RELEASE     12
         ASSIGN      17,V17
         JOIN        5
         ASSIGN      31,V17
         TRANSFER    ,C[illegible]
  [illegible] ASSIGN  16,V16
         QUEUE       16
         SEIZE       16
         DEPART      16
         ASSIGN      30,CS16
         ADVANCE     V16
         RELEASE     16
         ASSIGN      17,V17
         ASSIGN      31,V17
         JOIN        7
         TRANSFER    ,C[illegible]
  [illegible] ASSIGN  31,C11CO
         EXAMINE     1,,JA[illegible]
         TRANSFER    ,FINA
  JA[illegible] EXAMINE 3,,SAN
         TRANSFER    ,CCPJ
  SA[illegible] TRANSFER ,FINA
  C[illegible] ASSEMBLE 2
         ASSIGN      13,V1[illegible]
         QUEUE       1[illegible]
         SEIZE       1[illegible]
         DEPART      18
         ASSIGN      30,QT18
         ADVANCE     V18
         RELEASE     18
         TRANSFER    ,FINA
  FI[illegible] ASSEMBLE 3
         ASSIGN      15,V19
         QUEUE       19
         SEIZE       19
         DEPART      19
         ASSIGN      29,QT19
         ADVANCE     V19
         RELEASE     19
```

```
        ASSIGN     20,V20
        QUEUE      20
        SEIZE      20
        DEPART     20
        ASSIGN     40,QT20
        ADVANCE    V40
        RELEASE    20
        TABULATE   1
        TABULATE   5
        TERMINATE  1
        FVARIABLE  15+(FN1/100)10
  2     FVARIABLE  12+(FN2/100)8
  3     FVARIABLE  10+(FN3/100)10
  4     FVARIABLE  10+(FN4/100)8
  5     FVARIABLE  40+(FN5/100)15
  6     FVARIABLE  10+(FN6/100)20
  7     FVARIABLE  5+(FN6/100)40
  8     FVARIABLE  20+(FN3/100)20
  9     FVARIABLE  10+(FN3/100)20
 10     FVARIABLE  20+(FN4/100)20
 11     FVARIABLE  5+(FN3/100)10
  2     FVARIABLE  30+(FN5/100)20
 13     FVARIABLE  (35/10)+(FN2/100)4
 14     FVARIABLE  4+(FN3/100)8
 15     FVARIABLE  35+(FN5/100)20
 16     FVARIABLE  10+(FN1/100)20
 17     FVARIABLE  (45/10)+(FN6/100)4
 18     FVARIABLE  15+(FN6/100)40
 19     FVARIABLE  10+(FN6/100)20
 20     FVARIABLE  12+(FN2/100)8
 21     FVARIABLE  70-V1
 22     FVARIABLE  70-V2
 23     FVARIABLE  70-V3
 24     FVARIABLE  70-V4
 25     FVARIABLE  70-V5
 26     FVARIABLE  70-V6
 27     FVARIABLE  70-V7
 28     FVARIABLE  70-V8
 29     FVARIABLE  70-V9
 30     FVARIABLE  70-V10
 31     FVARIABLE  70-V11
 32     FVARIABLE  70-V12
 33     FVARIABLE  70-V13
 34     FVARIABLE  70-V14
 35     FVARIABLE  70-V15
 36     FVA ABLE   70-V16
 37     FVARIABLE  70-V17
 38     FVARIABLE  70-V18
 39     FVARIABLE  70-V19
 40     FVARIABLE  70-V20
 42     FVARIABLE  P1+P2+P3+P4+P5+P6+P7+P8+P9+P10+P11+P12+P13+P14+P15
 43     FVARIABLE  P16+P17+P18+P19+P20
 41     FVARIABLE  V42+V43
 44     FVARIABLE  P21+P22+P23+P24+P25+P27+P29+P30
 46     FVARIABLE  P32+P33+P34+P36+P38+P39+P40
 45     FVARIABLE  V44+V46+V41
 51     FVARIABLE  P26+1
 52     FVARIABLE  P26+2
 53     FVARIABLE  P26+3
 54     FVARIABLE  P26+4
  1     TABLE      V45,270,50,10
  5     TABLE      V45,120,5,30
```

```
100    STORAGE     7
       START       100
       CLEAR
100    STORAGE     6
       START       100
       CLEAR
100    STORAGE     5
       START       100
       CLEAR
100    STORAGE     4
       START       100
       CLEAR
100    STORAGE     3
       START       100
       CLEAR
100    STORAGE     2
       START       100
       REPORT
       OUTPUT
       EJECT
       GRAPH       TF,5
       ORIGIN      55,5
       X           ,1,3,125,1,30
       Y           0,1,30,1
100    STATEMENT   3,19,GRAPH OF TOTAL TIME
       ENDGRAPH
/*EOF
```

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) University of Florida	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP Unclassified

3. REPORT TITLE

"Project Management Using GPSS/360"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)

Hicks, Philip E. and
Jain, Suresh, K.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May 1969		3

8a. CONTRACT OR GRANT NO. DAn C04 06C 0002	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Report No. 19
b. PROJECT NO. 2T0 14501B81B	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. AVAILABILITY/LIMITATION NOTICES

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	ARO-Durham

13. ABSTRACT

A number of examples of complex precedence relationships in project management networking are considered employing the GPSS/360 program. The examples illustrate that GPSS/360 can be employed to develop project management information not readily attainable employing standard project management programs.